and back swept embodiments, the inner transition point is illustrated as being radially outward of the airfoil root. However the invention also comprehends a blade whose inner transition point (axially forwardmost point for the swept back embodiment and axially aftmost point for the forward swept embodiment) is radially coincident with the leading edge of the root. This is shown, for example, by the dotted leading edge 28" of FIG. 2.

The invention has been presented in the context of a fan blade for a gas turbine engine, however, the invention's applicability extends to any turbomachinery airfoil wherein flow passages between neighboring airfoils are subjected to multiple shocks.

CM

We claim:

1. A turbomachinery blade for a turbine engine having a cascade of blades rotatable about a rotational axis so that each blade in the cascade has a leading neighbor and a trailing neighbor, and each blade cooperates with its neighbors to define flow passages for a working medium gas, the blade cascade being circumscribed by a case and under some operational conditions an endwall shock extends a limited distance radially inward from the case and also extends axially and circumferentially across the flow passages, and a passage shock also extends across the flow passages, the turbomachinery blade including an airfoil having a leading edge, a trailing edge, a root, a tip and an inner transition point located at an inner transition radius radially inward of the tip, the blade characterized in that at least a portion of the leading edge radially outward of the inner transition point is swept and a section of the airfoil radially coextensive with the endwall shock extending from the leading neighbor intercepts the endwall shock so that the endwall shock and the passage shock are coincident.

2. A turbomachinery blade for a turbine engine having a cascade of blades rotatable about a rotational axis so that each blade in the cascade has a leading neighbor and a trailing neighbor, and each blade cooperates with its neighbors to define flow passages for a working medium gas, the blade cascade being circumscribed by a case and under some operational conditions an endwall shock extends a limited distance radially inward from the case and also extends axially and circumferentially across the flow passages and a passage shock also extends across the flow passages, the turbomachinery blade including an airfoil having a leading edge, a trailing edge, a root, a tip located at a tip radius, an inner transition point located at an inner transition radius radially inward of the tip, and an outer transition point at an outer transition radius radially intermediate the inner transition radius and the tip radius, the blade having a tip region bounded by the outer transition radius and the tip radius, and an intermediate region bounded by the inner transition radius and the outer transition radius, the blade characterized in that the leading edge is swept in the intermediate region at a first sweep angle which is generally nondecreasing with increasing radius, and the leading edge is swept over at least a portion of the tip region at a second sweep angle which is generally nonincreasing with increasing radius so that the section of the airfoil radially coextensive with the endwall shock extending from the leading neighbor intercepts the endwall shock so that the endwall shock and the passage shock are coincident.

3. The turbomachinery blade of claim 1 or 2 characterized in that the inner transition radius is coincident with the root at the leading edge of the blade.

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Sub C2

4. A turbomachinery blade for a gas turbine engine fan comprising a plurality of blades mounted for rotation about a fan axis with neighboring blades forming passages for a working medium gas, wherein:

the blade has a configuration enabling the fan to rotate at speeds providing supersonic flow velocities in at least a portion of each passage causing the formation of a shock in the gas adjacent an inner wall of a case forming an outer boundary for the working medium gas flowing through the passages;

the blade has a leading edge with an intermediate region and a tip region outward of the intermediate region and extending to a tip end of the blade, the intermediate region being swept rearward at a sweep angle that does not decrease; and

the tip region is translated forward to provide a sweep angle that causes the blade to intercept the shock.

5. The turbomachinery blade of claim 4, wherein the tip region begins at an outward boundary of the intermediate region and throughout the tip region the sweep angle is less than the sweep angle at the outward boundary of the intermediate region.

6. The turbomachinery blade of claim 5, wherein the sweep angle decreases throughout the tip region.

7. The turbomachinery blade of claim 6, wherein the sweep angle increases throughout the intermediate region.

8. The turbomachinery blade of any one of claims 4 to 7, wherein an inward boundary of the intermediate region is coincident with a root end of the blade.

9. The turbomachinery blade of any one of claims 4 to 7, wherein the leading edge of the blade has an inner region beginning at a root end of the blade and extending to an inward boundary of the intermediate region, the inner region being swept forward.

Sub C3

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Sub A2

10. A blade for a gas turbine engine fan comprising a plurality of blades mounted for rotation within a case circumscribing the blades and forming an outer boundary for a working medium gas flowing through passages formed by neighboring blades, wherein:

the blade has a configuration enabling the fan to rotate at speeds providing supersonic flow velocities in at least a portion of each passage;

the blade has a leading edge with an intermediate region and a tip region beginning at an outward boundary of the intermediate region and extending to a tip end of the blade, the intermediate region having a sweep angle that does not decrease from the beginning to the outward boundary of the intermediate region; and

throughout the tip region the sweep angle is less than the sweep angle at the outward boundary of the intermediate region.

11. The blade of claim 10, wherein the intermediate region is swept rearward and the tip region is translated forward.

12. The blade of claim 10, wherein the intermediate region is swept forward and the tip region is translated rearward.

13. The blade of claim 10, wherein the tip region sweep angle decreases throughout the tip region.

14. The blade of claim 13, wherein the intermediate region sweep angle increases throughout the intermediate region.

Sub A3

15. The blade of any one of claims 10 to 14, wherein an inward boundary of the intermediate region is coincident with a root end of the blade.

16. The blade of claim 10, wherein:

the intermediate region is swept rearward and the tip region is translated forward; and

the leading edge of the blade has an inner region beginning at a root end of the blade and extending to an inward boundary of the intermediate region, the inner region being swept forward.

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12 ~~17~~. The blade of claim ~~18~~, wherein:

the intermediate region sweep angle increases throughout the intermediate region; and

the tip region sweep angle decreases throughout the tip region.

Sub A4

18. A blade for a gas turbine engine fan comprising a plurality of blades mounted for rotation within a case circumscribing the blades and forming an outer boundary for a working medium gas flowing through passages formed by neighboring blades, wherein:

the blade has a configuration enabling the fan to rotate at speeds providing supersonic flow velocities in at least a portion of each passage;

the blade has a leading edge with an intermediate region and a tip region beginning at an outward boundary of the intermediate region and extending to a tip end of the blade, the intermediate region being swept rearward at a sweep angle that does not decrease from the beginning to the outward boundary of the intermediate region; and

the tip region is translated forward from the outward boundary of the rearwardly swept intermediate region.

19. The blade of claim 18, wherein the tip region maintains a rearward sweep throughout the tip region.

Sub A6

20. Turbomachinery for a gas turbine engine, comprising a plurality of blades mounted for rotation within a case circumscribing the blades and forming an outer boundary for a working medium gas flowing through passages formed by neighboring blades, wherein:

Sub A5

each blade has a configuration enabling the turbomachinery to rotate at speeds providing supersonic working medium gas velocities at least in the vicinity of the passages proximate to the case;

each blade has a leading edge with a swept intermediate region and a swept tip region beginning at an outward boundary of the intermediate region and extending to a tip end of the blade, the intermediate region of each blade having a sweep angle that does not decrease from the beginning to the outward boundary of the intermediate region; and

throughout the tip region the sweep angle of each blade is less than the sweep angle at the outward boundary of the intermediate region.

21. The turbomachinery of claim 20, wherein the intermediate region of each blade is swept rearward and the tip region is translated forward.

Sub C8 ?

22. The turbomachinery of claim 21, wherein:

the intermediate region sweep angle of each blade increases throughout the intermediate region; and

the tip region sweep angle of each blade decreases throughout the tip region.

Sub A6

23. The turbomachinery of claim 22, wherein the leading edge of each blade has an inner region beginning at a root end of the blade and extending to an inward boundary of the intermediate region, the inner region being swept forward.

24. The turbomachinery of claim 20, wherein the intermediate region of each blade is swept forward and the tip region is translated rearward.

25. The turbomachinery of claim 24, wherein the tip region sweep angle of each blade decreases throughout the tip region.

26. The turbomachinery of claim 25, wherein the intermediate region sweep angle of each blade increases throughout the intermediate region.

Sub A7

27. A gas turbine engine fan comprising a plurality of identical blades, each blade being mounted for rotation within a case circumscribing the blades and having an inner wall forming an outer boundary for a working medium gas flowing through passages formed by neighboring blades, wherein:

each blade has a configuration enabling the fan to rotate at speeds providing supersonic working medium gas velocities in the vicinity of the passages proximate to the case;

each blade has a leading edge with an inner region, an intermediate region and a tip region, the inner region beginning at a root end of

the blade and extending to an inward boundary of the intermediate region, and the tip region extending from an outward boundary of the intermediate region to a tip end of the blade; and

the inner region is swept forward, the intermediate region is swept rearward at a sweep angle that does not decrease, and the tip region is translated forward from the outward boundary of the intermediate region.

21 ~~28~~. The gas turbine engine fan of claim 20 ~~27~~, wherein the tip region maintains a rearward sweep throughout the tip region.

22 ~~29~~. The gas turbine engine fan of claim 20 ~~27~~, wherein:

the intermediate region sweep angle of each blade increases throughout the intermediate region; and

the tip region of each blade is swept at a sweep angle that decreases throughout the tip region.

30. A blade for a gas turbine engine rotatable within a case at speeds providing supersonic flow over at least a portion of the blade, wherein the blade leading edge has a rear swept middle region ending at a tip region that is translated forward from the end of the middle region.

27 ~~31~~. The blade of claim 26 ~~30~~, wherein the tip region maintains a rearward sweep throughout the tip region.

32. The blade of claim 30, wherein the leading edge has a forward swept inner region.

29 ~~33~~. The blade of claim 28 ~~32~~, wherein the sweep angle of the middle region increases throughout the middle region.

30 ~~34~~. The blade of claim 29 ~~33~~, wherein throughout the tip region the sweep angle is less than the sweep angle at the end of the middle region.

31 ~~35~~. The blade of claim 30 ~~34~~, wherein the sweep angle of the tip region decreases from the end of the middle region to a tip end of the blade.

Sub a2

36. A blade for a gas turbine engine rotatable within a case at speeds providing supersonic flow over at least a portion of the blade, wherein the blade leading edge has a forward swept middle region ending at a tip region that is translated rearward from the end of the middle region.

33 ~~37~~. The blade of claim 32 ~~36~~, wherein the tip region maintains a forward sweep throughout the tip region.

34 ~~38~~. The blade of claim 32 ~~36~~, wherein the leading edge has a rear swept inner region.

35 ~~39~~. The blade of claim 34 ~~38~~, wherein the sweep angle of the middle region increases throughout the middle region.

36 ~~40~~. The blade of claim 35 ~~39~~, wherein throughout the tip region the sweep angle is less than the sweep angle at the end of the middle region.

37 ~~41~~. The blade of claim 36 ~~40~~, wherein the sweep angle of the tip region decreases from the end of the middle region to a tip end of the blade.

add B'

add C14

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